Space Weather Technical Forecast

Issued on Tuesday, 09 May 2023 at 01:11 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

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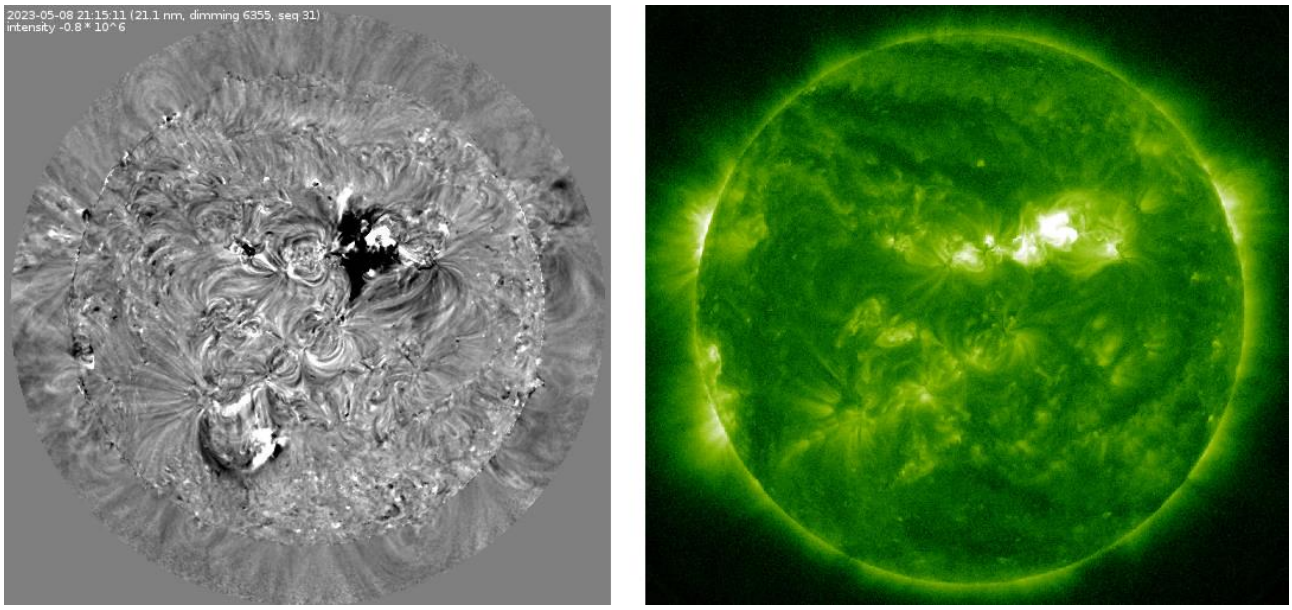
Space Weather Forecast Headline: G1/G2 Minor/Moderate geomagnetic storm Expected late 10 into 11 May. S1/Minor Solar Radiation Storm Expected through to midweek UTC, then most likely easing. Ongoing Likely R1/R2 Minor/Moderate radio blackout risk.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has remained Moderate over the past 24 hours, with activity measured at GOES16 bookended by the tail of the long-period 07/2323 peak M1.6 flare starting the 24-hour period, and an impulsive M2.3 at 08/2025UTC. Both of these flares emanated from AR3296, which saw rapid development of its low-latitude intermediate spots and some associated penumbral growth, finishing the period as a Dac/Beta-Gamma.

Figure 0: Left: time-integrated AIA211 dimming associated with the 08/2025UTC M2.3 flare from AR3296 (processing courtesy of SIDC ROB). Also shown is the same event in AIA094, right. Any arising ejecta from this event is yet to be determined, pending imagery.



The above sunspot group was one of up to six on the current disc, with a new bipolar region developing in the northeastern quadrant. The largest and nominally most complex sunspot group on the disc saw the emergence of a new high latitude spot around its main penumbral leader, with this potentially showing a tenuous delta configuration along with another minor leading spot to give an Ekc/Beta-Delta classification by the period's end. The three other remaining groups on the disc were less remarkable, all being unipolar or minor dipoles in decay.

A full halo CME was associated with the peak M1.6 flare that narrowly preceded this 24-hour

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period from AR3296. Although much of the ejecta appears to be directed to the northwest, an Earth-directed component is expected and has been modelled.

A minor filament apparently erupted from the northwestern quadrant to the west of AR3296 at 08/1000UTC, although there was no obvious ejecta subsequently observed on coronagraph imagery.

Despite its apparently impulsive nature, a CME is considered a possibility from the late M2.3 flare and AIA211 dimming from AR3296. Imagery is pending for this event.

Solar Wind / Geomagnetic Activity: The solar wind, as recorded by DSCOVR at L1, was mainly suggestive of a positive polarity fast wind, most likely that from coronal hole 01 or perhaps 99 given the mainly positive phi angle (away from the Sun). This became less clear-cut later in the period, with a period spent in negative phi signposted by possible SSBCs at 13 and 17UTC.

The solar wind rose from Slightly Elevated levels near 450km/s to reach an Elevated peak just shy of 550, before moderating somewhat into the UTC evening. The IMF over the same period fell from a Slightly Elevated early peak of 12nT, with the north-south component becoming more constrained in its scope with time, falling from -12 and +10nT to within +/-5nT to end the 24 hours. The solar wind density was also Slightly Elevated at times, with an early peak in the mid-teens ppcc falling into Background territory for a time, before a second short-lived peak of 20ppcc around the 13UTC SSBC, again moderating thereafter.

The net result of the above solar wind measures was Quiet to Active, with a provisional Kp '4o' in the 00-03UTC interval.

Energetic Particles / Solar Radiation: High energy proton flux (greater than 10MeV), as measured at GOES16, surpassed S1 in the period, rising from Background to 27pfu at 2330UTC, crossing the S1 threshold of 10pfu itself at 08/1145UTC.

High energy electron flux (greater than 2MeV), as measured at GOES16, has been at Normal Background levels. The 24-hour integrated fluence has been well below Active levels. At 09/0001UTC 1.3e6 integrated pfu was recorded.

Four-Day Space Weather Forecast Summary

Solar Activity: Isolated Moderate activity remains Likely throughout the period, mainly from AR3296 and perhaps also AR3297. None of the main front-sided regions leave the disc in the period, and there are no major arrivals expected.

Solar Wind / Geomagnetic Activity: A full halo CME was observed in coronagraph imagery with the M1.6 flare from AR3296 at 07/2323UTC. Although much of the ejecta appears to be directed towards the northwest an Earth-directed component is expected and has been modelled to arrive at Earth either on late 10 or early 11 May. In addition to this, a further CME candidate is awaiting imagery.

Earth is currently in a fast wind regime, either that from CH01/+ else CH99/+. Elevated to slightly elevated winds should ease to background through the first 48 hours of the forecast. A minor resurgence in the solar wind may occur late on 11 May due to yet another positive polarity coronal hole - CH02/+. Any impacts are expected to be weak based on persistence, in any case most likely swamped by the concurrent arrival of the CME (detailed above).

On 09 May Quiet to Unsettled activity is expected, giving way to an Expected G1-G2 (Minor to Moderate) storm, either late on 10 May or else early 11 May, with a Slight Chance of G3 (Strong) geomagnetic storm levels being reached. This risk should recede to perhaps a vestigial Slight

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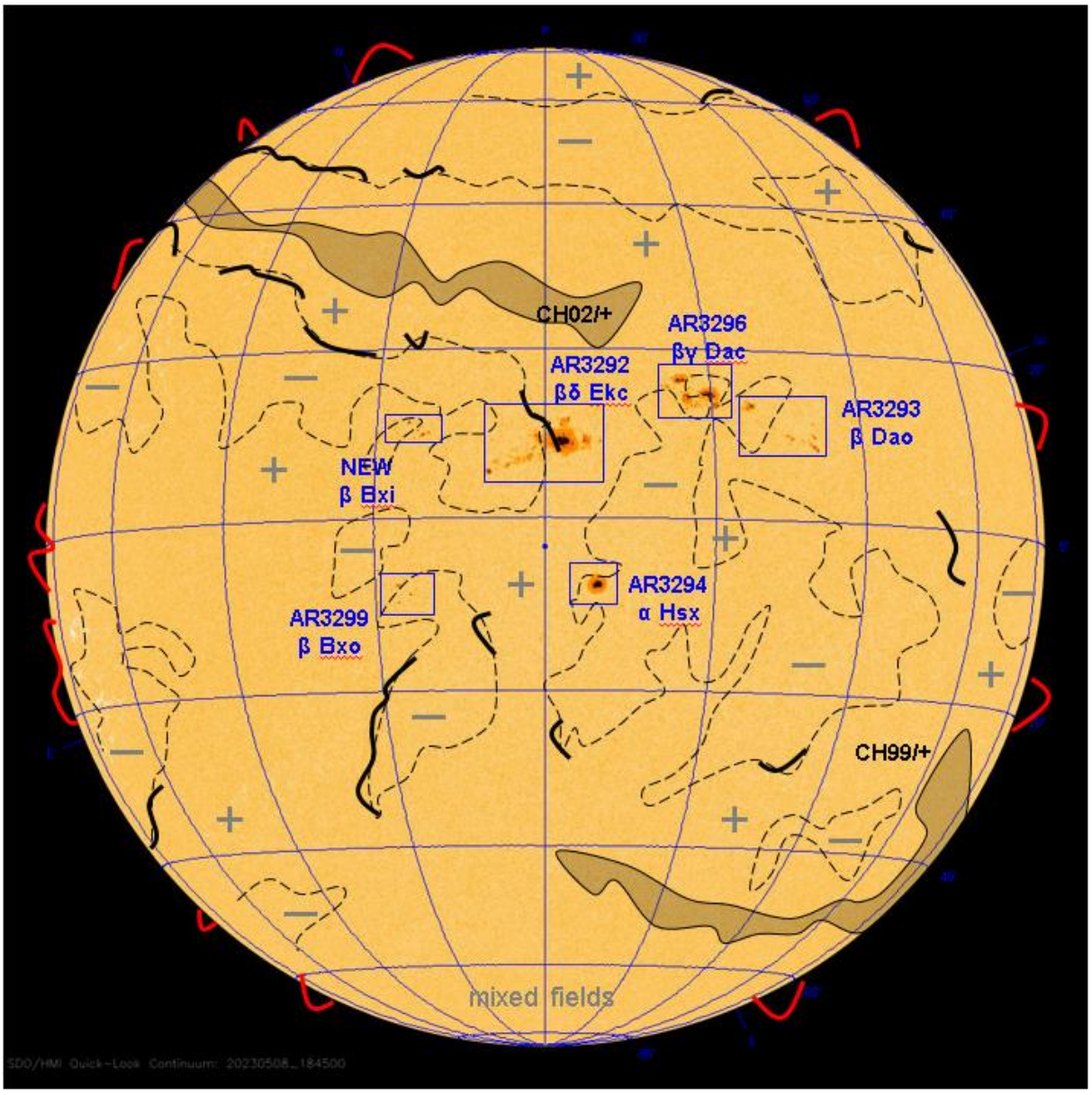
Chance of G1 by day four, Friday 12 May.

Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux is Likely to remain above S1 on day one, Tuesday 09 May, with the duration now perhaps extended by further M-class activity from AR3296, with this to be confirmed. The chances of S1 being maintained after midweek should fall - in the absence of further significant flare activity.

High energy (greater than 2MeV) electron flux is expected to persist at Normal Background levels, with a possibility of reaching diurnally High levels on 10 May ahead of the anticipated CME arrival either late 10 or early 11 May. The associated 24-hour fluence is forecast to persist below the Active threshold.

Figure 1. Solar Analysis Valid 09/1845UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

A full halo CME was observed in coronagraph imagery with the M1.6 flare from AR3296 at 07/2323UTC. Although much of the ejecta appears to be directed towards the northwest, an Earth-directed component is expected and has been modelled to arrive at Earth either late on 10 May or early 11 May. In addition to this, the M2.3 flare from 08/2025UTC appears likely to have generated a CME and imagery is awaited.

Earth is currently thought to be under the influence of a positive polarity fast wind, namely that from CH99/+ and/or CH01/+, perhaps polluted at first by minor transient(s) and later by brief SSBCs. Elevated to Slightly Elevated winds should ease to background either on 09 or 10 May as the influence of the coronal hole(s) wanes.

Some enhancement in the solar wind may then occur late on 11 May due to CH02/+, however any impacts are expected to be weak based on persistence, and most likely masked by the expected arrival of the CME that left the sun on 07 May, either late 10 or early 11 May. Solar winds are most likely to increase to Elevated levels with the CME, bringing an increased risk of significant geomagnetic activity.

On 09 May Quiet to Unsettled activity is expected, giving way to an Expected G1-G2 (Minor to Moderate) storm, either late on 10 May or else early 11 May, with a Slight Chance of G3 (Strong) geomagnetic storm levels being reached. This risk should recede to perhaps a vestigial Slight Chance of G1 by day four, Friday 12 May.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	1	80	80	20
Strong	G3	No	1	10	10	1
Severe	G4	No	1	3	3	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
08/0300	Full	Flare	AR3296 centre-disc	950km/s	10/2100 +/-9 hours	N/A

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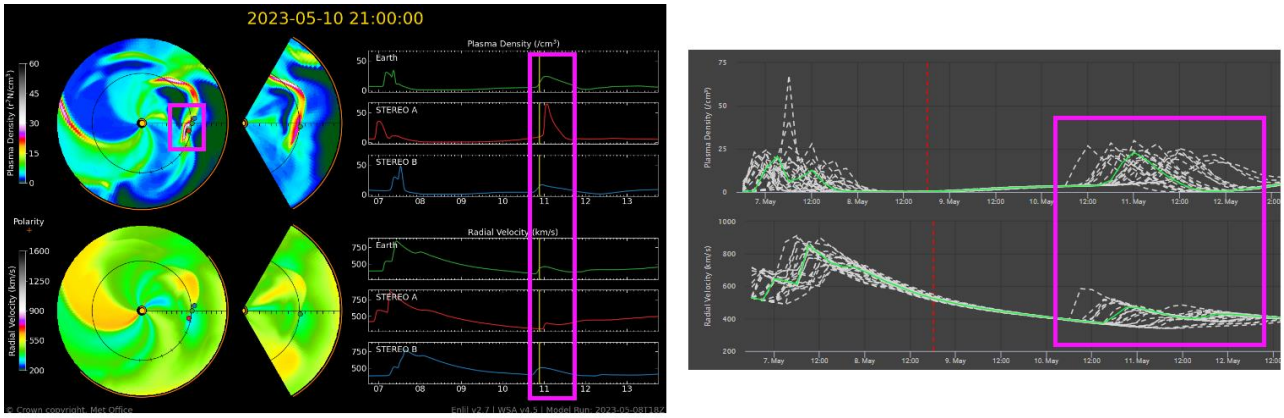
Figure 2: Latest MOSWOC Enlil run and ensemble, showing the 07/2323UTC M1.6 flare CME boxed in magenta, with the simulation paused around the time of arrival in the deterministic run (10/2100UTC). The range of arrival time solutions offered by the ensemble can be seen to be particularly large. This run does not account for any ejecta from the later M2.3 CME – with imagery awaited.



Radio Blackouts - X-Ray Flares:

Isolated Moderate activity is expected to continue, with further M-flares Likely and a Slight Chance of isolated X-class flares.

While there are up to six sunspot regions on the disc at present, the main sources of risk are AR3296 and AR3297, both of which are in the central northwestern quadrant and show some inter-connection. The former has so far proved the most active, with a pair of M-class flares and rapid intermediate spot growth observed. AR3297 has so far been less emissive, but recent peripheral leading sunspot development may now have resulted in a pair of tenuous Mt Wilson delta spots in the group, making this one to watch.

Regarding the balance of sunspot regions on the Earth-facing side, none of the significant contributors to the Likely M-class risk leave the disc in the period, and there are no significant returning regions due, leading to a flat four-day trend.

X Ray Flares	**Level**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability			**(%)**	**(%)**	**(%)**	**(%)**
Active	**R1-R2 M Class**	Yes	70	70	70	70
Very Active	**R3 to R5 X Class**	No	15	15	15	15

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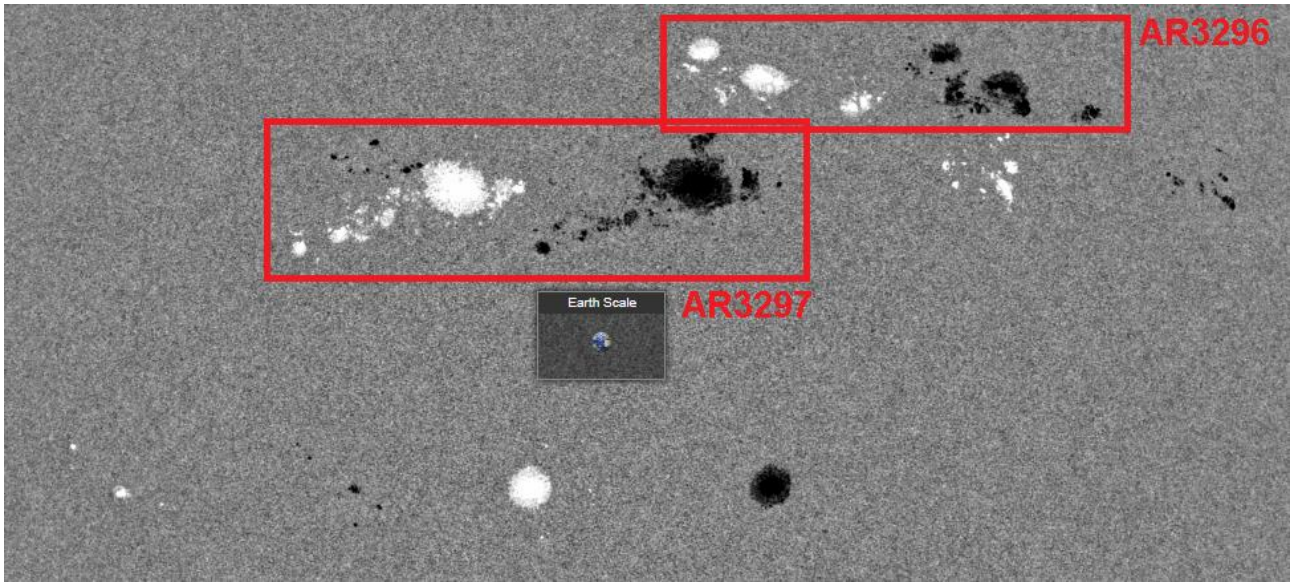
Figure 3: 24-hour growth trends in the central sunspot regions, as shown in HMIIF footprint difference imagery generated using Helioveiwer.org. Sunspot footprints as of 07/2115UTC are shown in white, with their appearance 24 hours later shown in black. Of most note are AR3297 and AR3296, which both show a proliferation of spots and some areal growth in that period.



Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux, as as observed by GOES16 has breached S1 in response to the long-duration M1.6 flare from AR3296 at 07/2323UTC. The current plateau near 25pfu may yet show another step-wise increase - should the M2.3 from AR3296 at 08/2025UTC have generated still more Earth-connecting protons, else show a very gradual descent back below later in the coming UTC working week. The proton forecast is thus relatively low confidence, as the assumed current plateau and gradual decline is reliant on there being no further significant events while the flux is elevated at GEO, and the raw disc probabilities suggest a 15% daily chance of their occurrence.

All considered, S1 is Expected for at least day one, Tuesday 09 May, perhaps with a further imminent step-wise increase afoot given the M2.3 flare, but probably falling short of S2. Probabilities of S1's continuation should fall later in the UTC week, but remain slightly above the 15% raw disc probability given the higher than background starting point and AR3296's apparent propensity for proton-rich events.

Radiation Storms	**Level (cm^{-2} sr^{-1} s^{-1})**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability (Exceedance)			**(%)**	**(%)**	**(%)**	**(%)**
Active	**≥ S1**	Yes	100	40	25	20
Very Active	**≥ S3 ***	No	5	5	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

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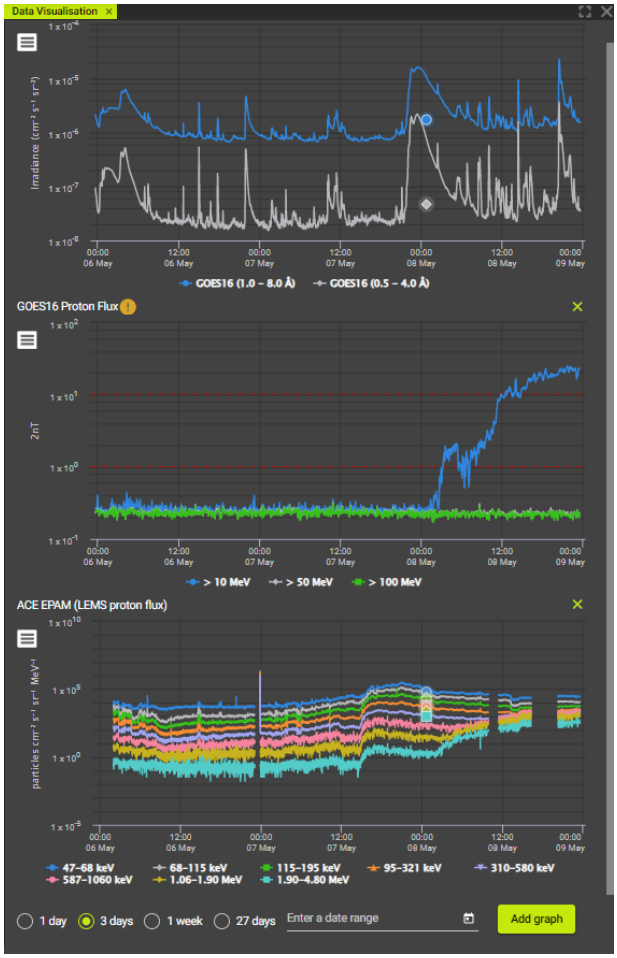
Figure 4: Past three days in GOES16 X-ray flux; greater than 10MeV proton flux and L1 ACE EPAM LEMS, showing reaction in solar radiation to the M1.6 flare. A further enhancment may yet occure should the M2.3 flare also have produced a proton storm.



High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) observed by GOES16 is at Normal Background levels and is expected to remain so given the lack of major sources of fast wind and the threat of intervening CME activity. This is in accordance with persistence and the latest MOSWOC REFM output, both of which would suggest a continuation near current comfortably sub-active fluence levels.

GEO Electron Environment	**Level (cm^{-2} sr^{-1} day^{-1})**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability (Exceedance)			**(%)**	**(%)**	**(%)**	**(%)**
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	10	5	5
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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